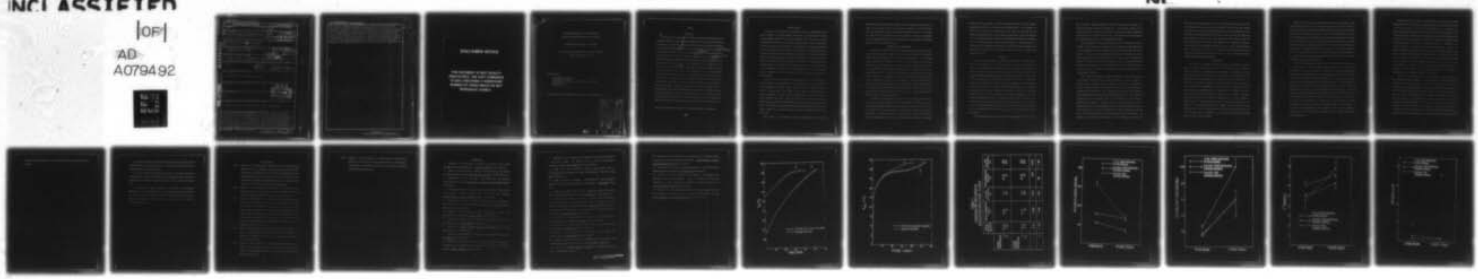
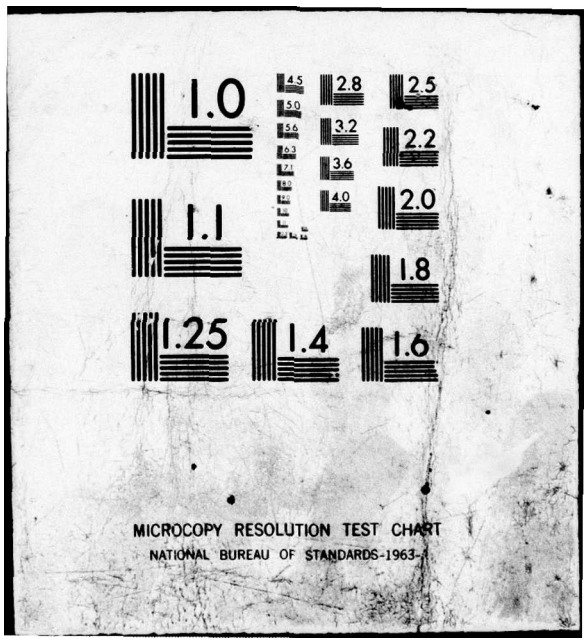
AD-A079 492 ARMY RESEARCH INST OF ENVIRONMENTAL MEDICINE NATICK MA F/G 6/19
HYPOTHERMIA INDUCED BY 5-THIO-D-GLUCOSE: EFFECTS ON TREADMILL P--ETC(U)
DEC 79 R P FRANCESCONI, M MAGER

UNCLASSIFIED NL

OF
AD
A079492



END
DATE
FILMED
2-80
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

DDC

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

REPORT NUMBER | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)

(6) Hypothermia Induced by 5-Thio-D-Glucose: Effects on Treadmill Performance in the Heat,

5. TYPE OF REPORT & PERIOD COVERED

LEVEL II

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

(10) Ralph P. Francesconi [redacted] Milton Mager

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS

U.S.Army Research Institute of Environmental Medicine, Natick, MA 01760

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

6.11.02.A Defense Research Sciences, Army 3E161102BS08

(17) 94132005 (16)

11. CONTROLLING OFFICE NAME AND ADDRESS

U.S. Army Medical Research and Development Command, Ft. Detrick, Frederick, MD 21701

(11)

12. REPORT DATE

7 Dec [redacted] 79

13. NUMBER OF PAGES

14

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

Same

(12) 25

15. SECURITY CLASS. (of this report)

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution of this document is unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

NA

DDC RECEIVED JAN 16 1980 A

18. SUPPLEMENTARY NOTES

NA

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

hyperthermic exhaustion, physical performance, hyperglycemia

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In continuing our studies on the effects of preinduced hypothermia on the endurance capacities, thermoregulatory responses, and clinical chemical indices of heat injury, 10 mg of 5-thio-D-glucose (5-TG) were administered intravenously to restrained rats kept at 4°C. When rectal temperatures (T_{re}) fell to 29-30°C, the rats were removed to a hot environment (35°C) where they exercised on a level treadmill (9.14 m/min) to hyperthermic exhaustion (T_{re} = 41.5-43°C). Preinduced hypothermia was effective in significantly ($p < .001$) prolonging the time to hyperthermic exhaustion. In these hypothermic rats increments in Tre (°C/min)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED 040 850

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

while on the treadmill were significantly (p .001) increased while rates of skin temperature (Tsk) heating were significantly (p .001) reduced when compared to normothermic controls. Administration of 5-TG effected significant (p .001) hyperglycemia which returned to control levels following the exhaustive run in the heat. Prolonged endurance times among the hypothermic rats caused slight increases in the levels of circulating plasma indices of heat/exercise injury. We concluded from these studies that hypothermia induced by 5-TG administration and cold exposure is effective in increasing the endurance capacity of rats exercising in the heat. However, homeostatic mechanisms supercede to increase the heating rate, and thus return Tre to equilibrium levels.

DISCLAIMER NOTICE

THIS DOCUMENT IS BEST QUALITY PRACTICABLE. THE COPY FURNISHED TO DDC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Hypothermia Induced by 5-Thio-D-Glucose: Effects on Treadmill Performance in the Heat

Ralph P. Francesconi and Milton Mager

US Army Research Institute of Environmental Medicine

Natick, Massachusetts 01760

Send proofs to:

Dr. Ralph P. Francesconi
Heat Research Division
US Army Research Institute of Environmental Medicine
Kansas Street
Natick, MA 01760

Running title: Preinduced hypothermia and treadmill performance

Abstract

In continuing our studies on the effects of preinduced hypothermia on the endurance capacities, thermoregulatory responses, and clinical chemical indices of heat injury, 10 mg of 5-thio-D-glucose (5-TG) were administered intravenously to restrained rats kept at 4°C. When rectal temperatures (T_{re}) fell to 29°C, the rats were removed to a hot environment (35°C) where they exercised on a level treadmill (9.14 m/min) to hyperthermic exhaustion (T_{re} = 41.5°C). Preinduced hypothermia was effective in significantly ($p < .001$) prolonging the time to hyperthermic exhaustion. In these hypothermic rats increments in Tre (°C/min) while on the treadmill were significantly ($p < .001$) increased while rates of skin temperature (Tsk) heating were significantly ($p < .001$) reduced when compared to normothermic controls. Administration of 5-TG effected significant ($p < .001$) hyperglycemia which returned to control levels following the exhaustive run in the heat. Prolonged endurance times among the hypothermic rats caused slight increases in the levels of circulating plasma indices of heat/exercise injury. We concluded from these studies that hypothermia induced by 5-TG administration and cold exposure is effective in increasing the endurance capacity of rats exercising in the heat. However, homeostatic mechanisms supercede to increase the heating rate, and thus return Tre to equilibrium levels.

Key words: hyperthermic exhaustion, physical performance, hyperglycemia

INTRODUCTION

Reports in the literature have described a variety of experimental techniques designed to maximize physical performance. Investigators have utilized pharmacological agents (7), nutritional regimens (1,24), as well as vitamin supplements (9) to either increase physical performance or reduce the physiological cost of exercise. While Strydom et al. (22) have demonstrated the efficacy of vitamin C supplements in reducing the time required for heat acclimatization, very few investigations have addressed the possibility of reducing the adverse effects of exercise during acute exposure to high ambient temperatures. Tal and Sulman (23) demonstrated the benefits of exogenously administered dehydroepiandrosterone in increasing the survivability of rats when passively exposed to an environmental temperature of 37°C, while Hubbard et al. (11) have shown the critical importance of ambient temperature on the endurance capacity of exercising rats.

Since it had been previously demonstrated that when rats exercise on a treadmill under a moderate (26°C) (11) or hot (35°C) (3) environmental temperature, hyperthermic exhaustion usually occurs at a rectal temperature (T_{re}) of 42.5-43°C. The consistent rate of body heating as well as the reproducibility of final T_{re} suggested that experimental manipulation of T_{re} might delay the onset of hyperthermic exhaustion. Thus, we examined the effects of preinduced hypothermia (T_{re}=33°C) on the endurance capacity of rats exercising in the heat (4,12). The results of these earlier experiments demonstrated that the hypothermic animals had an endurance capacity which was increased 62% over that of controls.

More recently, we completed a series of experiments in mice which

demonstrated marked hypothermic effects of 5-thio-D-glucose (5-TG) when this agent was administered while the animals were exposed to cold (4°C) (5,13). Since the experimental animals demonstrated extreme sensitivity to relatively low doses of 5-TG, we hypothesized that the hypothermia induced by this agent and cold exposure would be even more efficacious in increasing the endurance capacity of rats exercising in the heat.

MATERIALS AND METHODS

The techniques utilized in the current experiments were essentially identical to those of our earlier report (4). Adult, male rats (Charles River Breeding Laboratories, Wilmington, MA) were used in all experiments. An indwelling jugular catheter was implanted on the day prior to experimentation for rapid withdrawal of 1 ml blood immediately prior to initiation of the exercise in the heat (T_{re}=29.4°C) and immediately subsequent to attaining hyperthermic exhaustion (T_{re}=41.7°C). To induce hypothermia in the experimental rats, 10 mg 5-TG/0.1 ml sterile, non-pyrogenic saline was administered intravenously followed immediately by exposure under restraint to 4°C ambient temperature. Control rats were treated identically, but injected only with physiological saline. The animals weighed from 280-340 g at the time of the experiment. Runs were made on a level treadmill at a speed of 9.14 m/min at an ambient temperature of 35°C and a relative humidity of 20-25%.

In several of these experiments the rats were food-deprived for 18h prior to the start of experimentation since we had earlier demonstrated the augmented thermoregulatory sensitivity of food-deprived animals to the 5-TG (5,13). Two groups of control animals, fed and 18h food-deprived, were used for proper comparisons. Ordinarily, sufficient hypothermia was achieved between 35-50 min after administration of the drug. Blood samples were rapidly centrifuged

(4000 x g, 4°C) and stored at -30°C for subsequent analysis. Plasma creatine phosphokinase (CPK) was determined by methods based on the technique of Oliver (17) as modified by Rosalki (18). Lactic acid was quantitated by the method described by Henry (8) while plasma potassium (K^+) levels were assayed on an IL flame photometer (Model 143, Instrumentation Laboratory, Lexington, MA) by methods described in their technical bulletin. Plasma glucose was measured after the procedures described by Slein (21). Statistical analyses were performed by the paired and non-paired t-test, and the null hypothesis was rejected at $p < .05$.

RESULTS

Fig. 1 illustrates the effects of hypothermia induced by 5-TG administration and cold exposure on the endurance capacity of animals exercising in the heat. The arrows denote the mean endurance time of the initially normothermic control animals as well as the originally hypothermic 5-TG treated rats. Since thermoregulatory characteristics between a group of normothermic, fed controls (n=7) and normothermic, food-deprived controls (n=6) were not statistically different, the results were combined for statistical purposes. The data tabulated in Fig. 1 show clearly the intensity of the preinduced hypothermia in the 5-TG treated animals, and also the significant increment in run-time for the same group of animals. Fig. 2 demonstrates the mean skin temperatue (T_{sk}) responses for the same groups of animals. It is important to observe the divergence in skin temperatures for the two groups of animals particularly after 20 min of exercise in the hot environment (e.g. at 25 min, $p < .01$; at 30 min, $p < .001$) despite the fact that both groups had similar starting T_{sk} due to the exposure to the 4°C environment.

Thermoregulatory data are summarized and quantitated in Table 1. Of the

five parameters compared between control and experimental animals, four demonstrated highly significant differences. Of particular interest is the difference noted in increments in T_{sk} which is indicative of reduced vasodilation and heat loss in the 5-TG treated rats. This is commensurate with the increased rate of heating (ΔT_{re}/min, $p < .001$) among these animals.

Fig. 3 illustrates the plasma glucose levels in the three groups of animals. Initially, it can be observed that treatment with 5-TG effects a highly significant ($p < .001$) hyperglycemia when compared with either fed or food-deprived control animals. Further, the often reported significant ($p < .001$) difference in plasma glucose levels between fed and fasted control rats can be noted. Following the exercise in the heat to hyperthermic exhaustion, circulating glucose levels are significantly reduced ($p < .01$) in the 5-TG-treated rats; in the fed, saline-treated animals as well as the fasted, saline-treated group trends toward reduction are not significantly different.

Fig. 4 depicts the effects of 5-TG administration and initial hypothermia on the response of plasma lactate levels to exercise in the heat. In the blood samples taken immediately prior to exercise in the heat to hyperthermic exhaustion, resting plasma lactate levels in the 5-TG, hypothermic animals are significantly ($p < .02$) elevated when compared to both groups of control animals. Final lactates (post-run) displayed rather large variability, but in each case were significantly ($p < .05$, minimal) higher at the conclusion of the exercise to hyperthermic exhaustion. Analogous results for circulating levels of K^+ are presented in Fig. 5. Parallel significant ($p < .05$, minimal) increments in plasma concentrations of K^+ occurred in both groups of initially normothermic animals, while 5-TG-treated, hypothermic animals displayed sharper increments. The steeper rise in circulating lactate and K^+ in the hypothermic rats may be

associated with their increased run times. The results depicted in Fig. 6 for CPK are consistent with some of our earlier findings (3). Because the high ambient temperature used in these experiments greatly reduces the expected run times to hyperthermic exhaustion, plasma CPK levels are quite variable and range from large increases in some rats to actual decreases in others when the pre- and post- blood samples are compared. What appears to be a significant increase in mean CPK levels of the initially hypothermic rats is actually mostly accounted for by a single value of 17,750 IU/L in the plasma of one experimental animal. Ordinarily, exercise bouts of longer duration are required before consistent responses of plasma CPK are observed.

DISCUSSION

The results of the present experiments are generally consistent with those which we had reported earlier for rats in which hypothermia was induced by either L-tryptophan or chlorpromozine administration in combination with cold exposure (4,12). Thus, we have shown clearly that hypothermia induced by 5-TG administration and cold exposure elicits markedly increased endurance time to hyperthermic exhaustion. While the animals were exercising on the treadmill, the non-equilibrium temperatures of the 5-TG-treated, hypothermic animals ($< 36^{\circ}C$) resulted in greater increments during exercise in the heat. The current results demonstrate, however, that this apparent drive to achieve homeostasis occurred concomitantly with decreased peripheral heat loss as evidenced by reduced rates of tail-skin heating among 5-TG-treated, hypothermic rats (Table 1). It is important to add that it is unlikely that 5-TG, of itself, affects peripheral heat loss since during cold exposure while the 5-TG-treated animals were achieving marked hypothermia, T_{sk} of 5-TG-treated and saline-treated control animals were not different.

Wilson et al. (25) have recently demonstrated that rats exercising at high treadmill speeds (42.6 m/min) can achieve thermal balance when the exercise is carried out under mild temperature conditions (22°C); however, they were unable to demonstrate a proportional increase in T_{re} at four treadmill speeds. Even at a room temperature of 42.5°C Ohara et al. (16) demonstrated that, for varying intervals, equilibrium T_{re} could be achieved in passively heated rats. However, results of the present experiments indicate that the combination of exercise and environmental temperature precluded the achievement of steady-state temperatures. It should be noted in Fig. 1 that for saline-treated animals increments in T_{re} were consistently observed through 25 min, the earliest time at which hyperthermic exhaustion was reached.

The intense hyperglycemic response to 5-TG administration (Fig. 3) which we have observed in even food-deprived animals is analogous to the response elicited by both central and peripheral administration of another analogue of D-glucose, 2-deoxy-d-glucose (6,14,15). It has been hypothesized that the intense circulatory hyperglycemia occurs simultaneously with central and peripheral tissue glucopenia resulting in decrements in heat production. This glucose efflux occuring in the first 30-45 min after 5-TG administration may be the result of glycogenolysis pursuant to sympathicoadrenomedullary discharge. The sharp reduction in plasma glucose levels in 5-TG-treated animals following exercise on the treadmill and the marked increases in heat production in these animals during this interval would be compatible with a rapid re-uptake and hypermetabolism of glucose in central and peripheral tissues. This increased re-uptake and hypermetabolism are commensurate with the increased thermogenic demands as well as the oxidative requirements of the initially hypothermic, exercising animals.

Circulating levels of lactate (2,3,20), potassium, (3,10), and creatine phosphokinase (2,3,10,19) have been repeatedly used as clinical chemical indices of exercise, exercise in the heat, and exercise/heat injury. Results of the present investigation are similar to those which we had demonstrated earlier (3). Thus, lactate and K^+ levels are both consistently elevated following exercise to hyperthermic exhaustion in all groups tested. It is noteworthy that the increased endurance capacity of the initially hypothermic animals is reflected in the sharper increments of circulating levels of both lactate and K^+. Clearly, the preinduced hypothermia did not reduce the control levels of these indices; in fact pre-run lactates were significantly increased in 5-TG, hypothermic rats. In these and some of our earlier experiments the results indicate that plasma CPK levels are less reliable as an index of heat/exercise induced injury. It should be noted that hyperthermic exhaustion is occurring after relatively brief periods of mild exercise. We believe that both the duration and intensity of the exercise are inadequate to elicit consistent changes in levels of CPK.

Thus, we have confirmed our earlier hypothesis that initial hypothermia can prolong the endurance capacity of rats exercising under hot environmental conditions by delaying the onset of hyperthermic exhaustion. While on the treadmill, the unit-time increments in T_{re} for those animals made hypothermic by 5-TG administration and cold exposure combined with the rapid reductions in levels of plasma glucose indicate a hypermetabolic compensation among these animals to return T_{re} to normal ranges. Similarly, reduced T_{sk} in this group suggests decreased peripheral heat loss, again probably a compensatory mechanism to achieve equilibrium T_{re}. Generally, the results indicate that the hypothermia induced by 5-TG and cold exposure do not have marked effects on plasma CPK, K^+, and lactate levels, but there are indications that the increased

treadmill time among these animals intensifies these responses after exercise in the heat.

The authors gratefully acknowledge the skilled technical assistance of SP5 Leonard Sakal and Mr. Stephen O'Connor. We express our gratitude to Mrs. A. Debra Caruso for typing the manuscript.

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official department of the Army position, policy, or decision, unless so designated by other official documentation.

In conducting the research described in this report, the investigators adhered to the Guide for Laboratory Animal Facilities and Care, as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal Resources, National Academy of Sciences-National Research Council.

Figure Legend

Fig 1. Effect of IV 5-thio-D-glucose administration (10 mg) and prior cold exposure (4°C) on T_{re} response to treadmill exercise in the heat (35°C). Mean values are depicted for n=6 in the 5-TG-treated group and n=13 in the saline-treated group. The arrows denote the mean times at which hyperthermic exhaustion was reached for both groups. Control animals received 0.1 ml sterile, non-pyrogenic physiological saline.

Fig 2. Effect of IV 5-thio-D-glucose administration (10 mg) and prior cold exposure (4°C) on the T_{sk} response to treadmill exercise in the heat (35°C). All parameters and conditions are as noted under Fig. 1.

Fig 3. Effect of 5-TG administration on plasma glucose levels in blood samples taken immediately prior to (pre-run) and following (post-run) exercise on a treadmill to hyperthermic exhaustion. Rats which were food-deprived were so for 18h prior to the start of the experiment. Mean values $\pm$ SEM are depicted for n=6 (5-TG, food deprived), n=6 (saline, food deprived), and n=7 (saline, fed). Control rats received 0.1 ml sterile, nonpyrogenic saline while 5-TG-treated animals were administered 10 mg 5-TG/0.1 ml saline.

Fig 4. Effect of 5-TG administration on plasma lactate levels in blood samples taken immediately before (pre-run) and after (post-run) exercise on a treadmill to hyperthermic exhaustion. All conditions and parameters are as noted under Fig. 3.

Fig 5. Effect of 5-TG administration on plasma potassium levels in blood samples taken immediately before (pre-run) and after (post-run) exercise to hyperthermic exhaustion. All conditions are identical to those noted under Fig. 3.

Fig 6. Effect of 5-TG administration on plasma levels of creatine phosphokinase in blood samples taken just before (pre-run) and after (post-run) exercise to hyperthermic exhaustion. All conditions are identical to those described under Fig. 3.

REFERENCES

1. Bergstrom, J., L. Hermansen, E. Hultman and B. Saltin. Diet, muscle glycogen, and physical performance. Acta Physiol. Scand. 71:140-150, 1967.

2. Bolter, C. P. and J. B. Critz. Changes in plasma enzyme activity elicited by running exercise in the dog. Proc. Soc. Exp. Biol. Med. 145:1359-1362, 1974.

3. Francesconi, R. P. and M. Mager. Heat-injured rats: pathochemical indices and survival time. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 45:1-6, 1978.

4. Francesconi, R. P. and M. Mager. Hypothermia induced by chlorpromazine or L-tryptophan: effects on treadmill performance in the heat. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 47:813-817, 1979.

5. Francesconi, R. P. and M. Mager. 5-Thio-D-glucose: Thermoregulatory effects in mice at various environmental temperatures. Amer. J. Physiol. Submitted for publication, 1979.

6. Freinkel, N., B. E. Metzger, E. Harris, S. Robinson and M. Mager. The hypothermia of hypoglycemia. N. Engl. J. Med. 287:841-845, 1972.

7. Gerald, M. C. Effects of (-) - amphetamine on the treadmill endurance performance of rats. Neuropharmacol. 17:703-704, 1978.

8. Henry, R. J. Clinical Chemistry - Principles and Technics. New York: Harper and Row, 1968, p. 664-666.

9. Howald, H. and B. Segesser. Ascorbic acid and athletic performance. Ann. NY Acad. Sci. 258:458-464, 1975.

10. Hubbard, R. W., W. D. Bowers, Jr. and M. Mager. A study of physiological, pathological, and biochemical changes in rats with heat - and/or work-induced disorders. Israel J. Med. Sci. 12:884-886, 1976.

11. Hubbard, R. W., W. T. Matthew, J. D. Linduska, F. C. Curtis, W. D. Bowers, I. Leav and M. Mager. The laboratory rat as a model for hyperthermic syndromes in humans. Am. J. Physiol. 231:1119-1123, 1976.

12. Mager, M. and R. P. Francesconi. Effect of hypothermia induced by chlorpromazine or L-tryptophan on treadmill performance in the heat. Fed. Proc. 38:1052, 1979.

13. Mager, M. and R. P. Francesconi. 5-Thio-D-glucose: thermoregulatory effects in mice at several environmental temperatures. Physiologist. 22:80, 1979.

14. Mager, M., S. Robinson and N. Freinkel. Drug modification of hypothermia induced by CNS glucopenia in the mouse. J. Appl. Physiol. 41:559-564, 1976.

15. Muller, E. E., A. Panerai, D. Cocchi, L. A. Frohman and P. Mantegazza. Central glucoprivation: some physiological effects induced by the intraventricular administation of 2-deoxy-D-glucose. Experientia. 29:874-876, 1973.

16. Ohara, K., F. Furuyama and Y. Isobe. Prediction of survival time of rats in severe heat. J. Appl. Physiol. 38:724-729. 1975.

17. Oliver, I. T. A spectrophotometric method for the determination of creatine phosphokinase myokinase. Biochem. J. 61:116-122, 1955.

18. Rosalki, S. B. An improved procedure for serum creatine phosphokinase determination. J. Lab. Clin. Med. 69:696-705, 1967.

19. Rose, L. I., J. E. Bousser and K. H. Cooper. Serum enzymes after marathon running. J. Appl. Physiol. 29:355-357, 1970.

20. Ruppert, R. D., A. Newman, D. G. Scarpelli and A. M. Weissler. The mechanisms of metabolic acidosis in heatstroke. Clin. Res. 12:356, 1967.

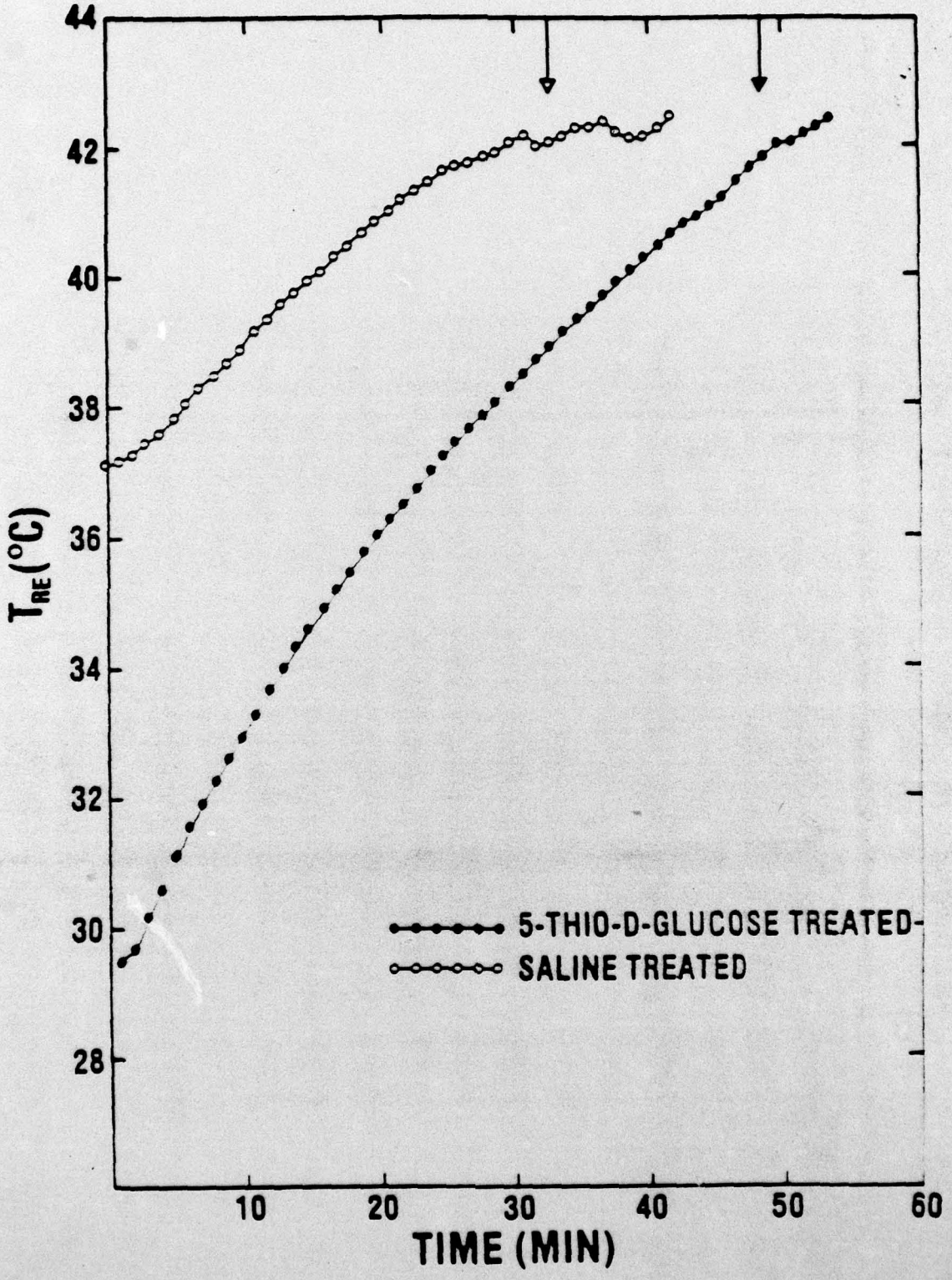
21. Slein, M. W. Methods of Enzymatic Analysis, H. U. Bergmeyer, ed., New York: Academic Press, 1963, p. 117.

22. Strydom, N. B., H. F. Kotze, W. H. vanderWalt and G. G. Rogers. Effects of ascorbic acid on rate of heat acclimatization. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 42:711-716, 1977.

23. Tal, E. and F. G. Sulman. Dehydroepiandrosterone - induced thyrotrophin release during heat stress in rats. J. Endocrinol. 67:99-103, 1975.

24. Ushakov, A. S., V. I. Myasnikov, B. D. Shestkov, A. N. Agureev, M. S. Belakovsky and M. P. Rumyantseva. Effect of vitamin and amino acid supplements on human performance during heavy mental and physical work. Aviat. Space Environ. Med. 49:1184-1187, 1978.

25. Wilson, N. C., C. V. Gisolfi, J. Farber and D. K. Hinrichs. Colonic and tail-skin temperature responses of the rat at selected running speeds. J. Appl. Physiol.: Respirat. Environ. Exercise Physiol. 44:571-575, 1978.


44
42
40
38
36
34
32
30
28
T_{RE}(°C)
10
20
30
40
50
60
TIME (MIN)
5-THIO-D-GLUCOSE TREATED
SALINE TREATED

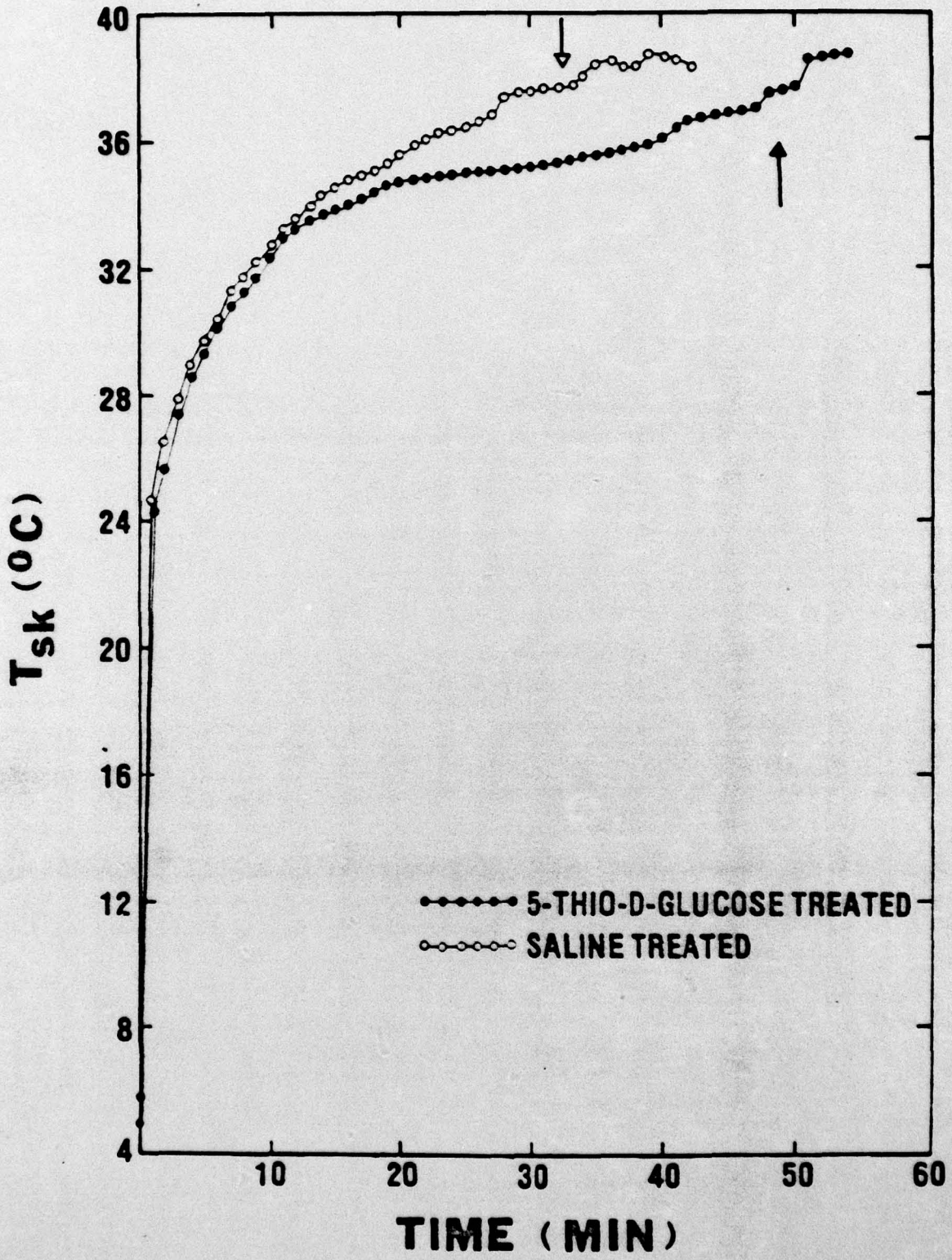
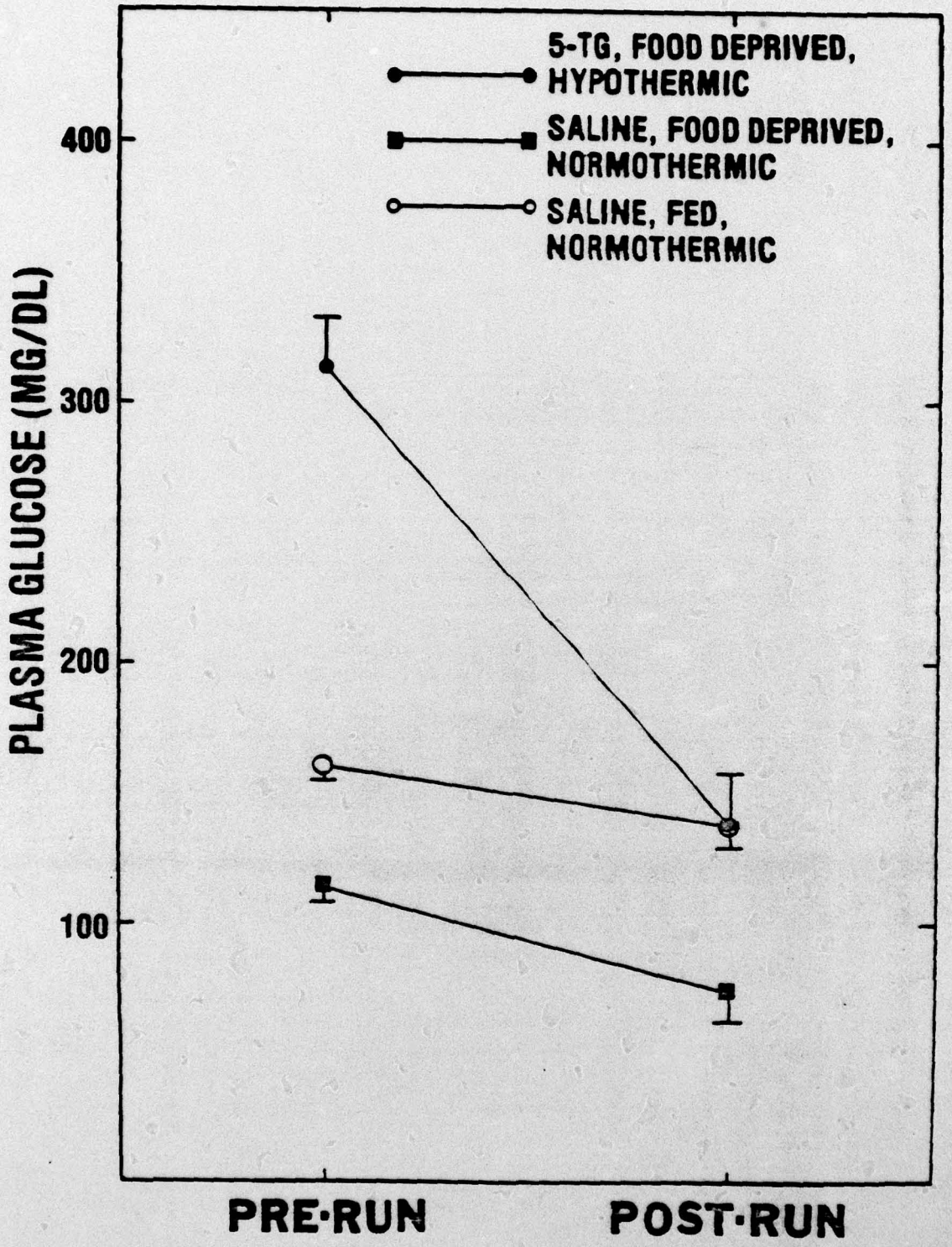
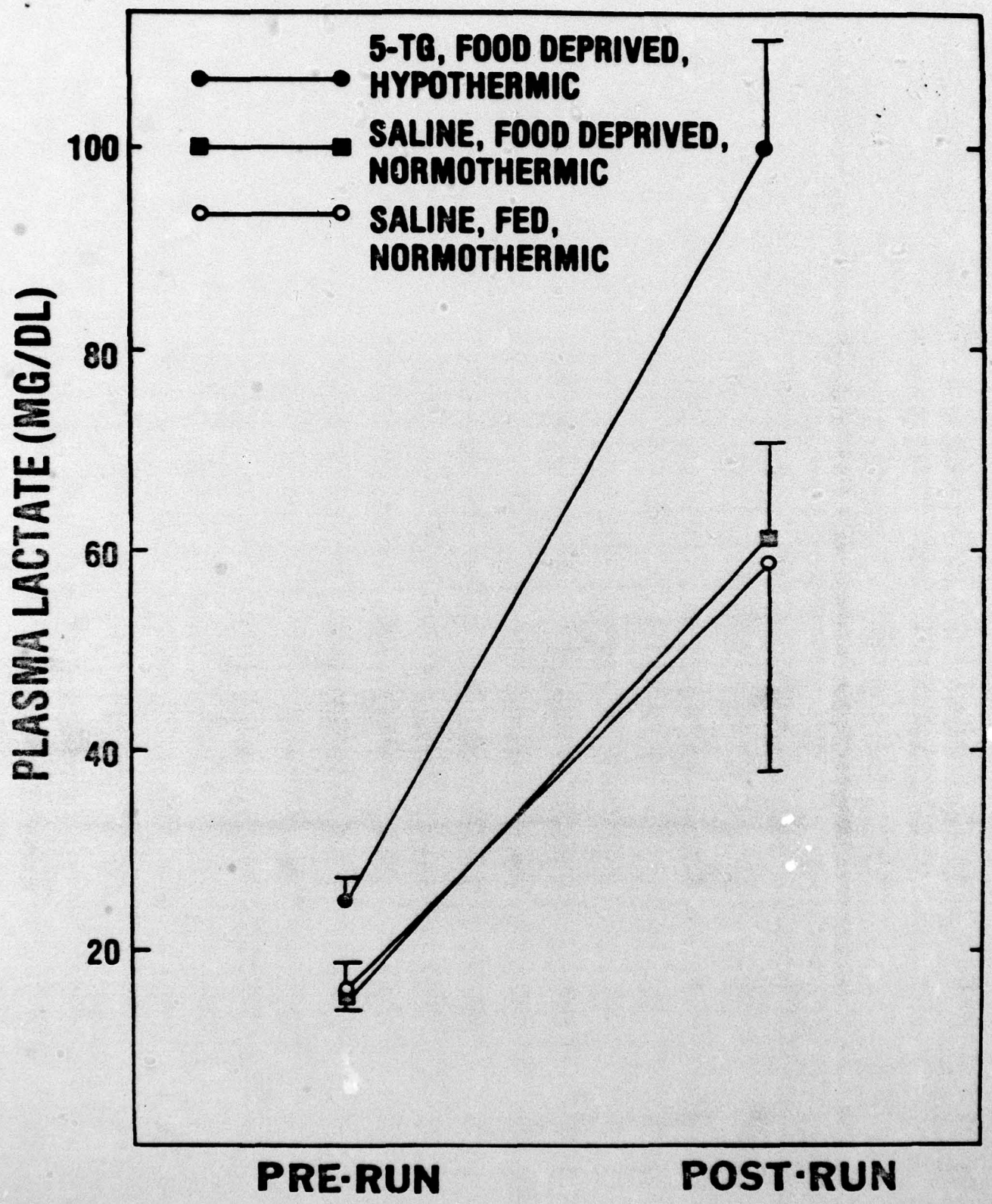
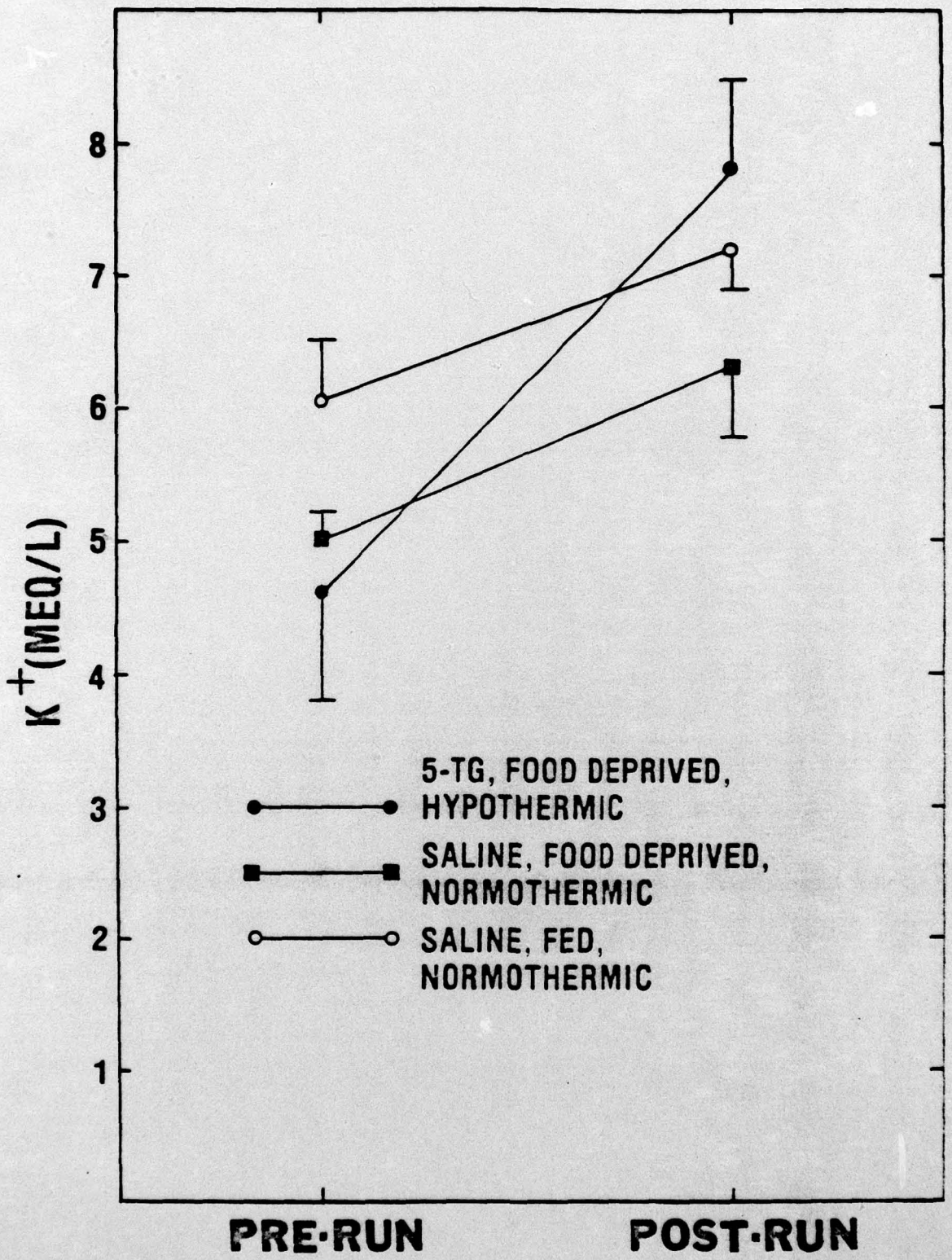

40
36
32
28
24
20
16
12
8
4
T_{sk} (°C)
10
20
30
40
50
60
TIME (MIN)
5-THIO-D-GLUCOSE TREATED
SALINE TREATED

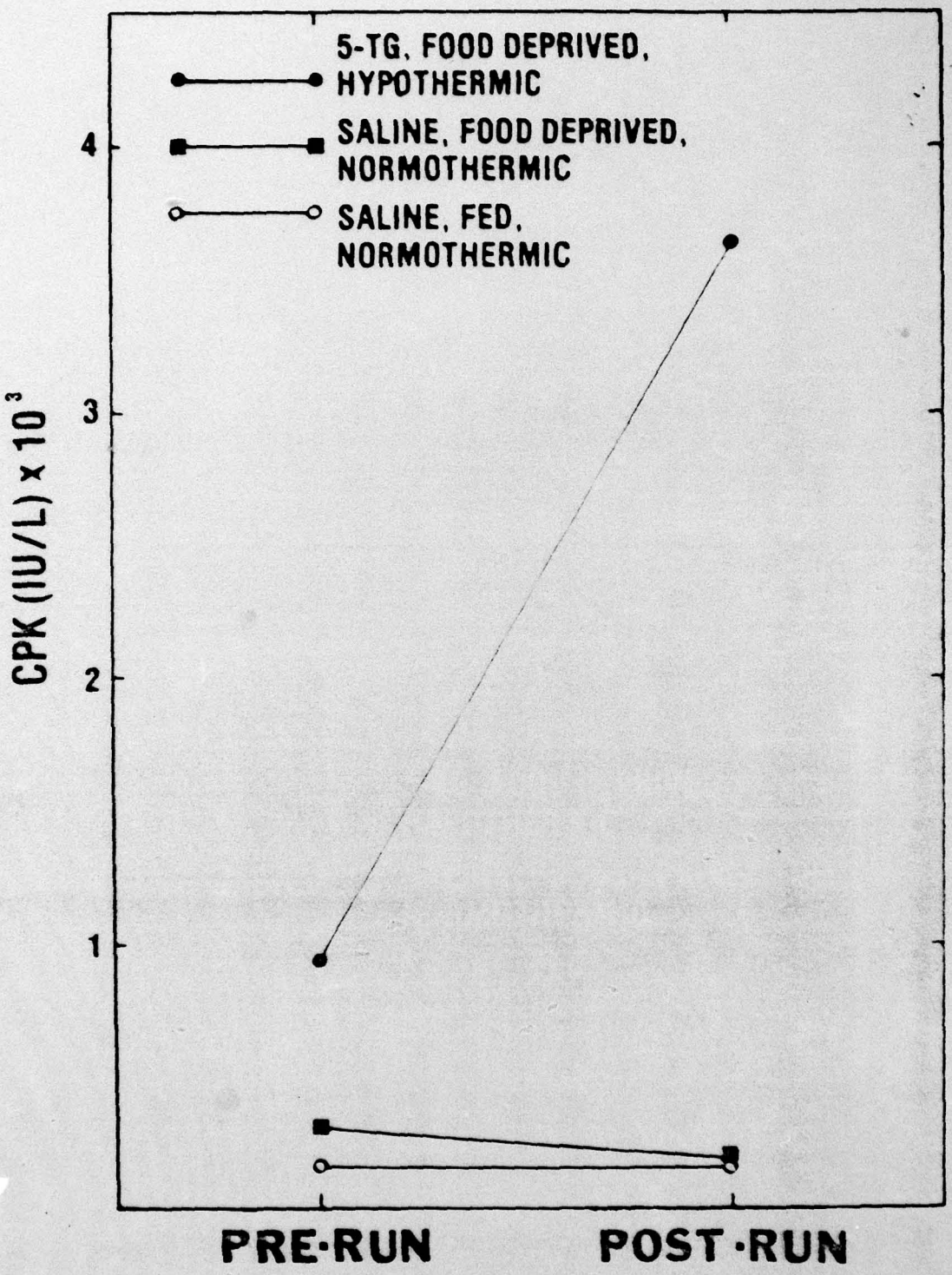
TABLE 1
SUMMARY OF THE RESULTS
DEMONSTRATED IN FIGS. 1 AND 2

	TIME ON TREADMILL (MINUTES)	RECTAL TEMPERATURE MAXIMUM (°C)	ΔT_{RE}/MIN ON TREADMILL (°C)	SKIN TEMPERATURE MAXIMUM (°C)	ΔT_{SK}/MIN ON TREADMILL (°C)
CONTROL NORMOTHERMIC					
$\bar{X}$	32.92	42.61	.171	37.41	.984
$SE_{\bar{X}}$	1.65	.09	.007	.43	.043
5-THIO-D-GLUCOSE HYPOTHERMIC					
$\bar{X}$	48.83	41.72	.253	37.06	.659
$SE_{\bar{X}}$	1.19	.28	.005	.34	.010
t	6.14	3.905	7.675	.514	5.012
p	<.001	<.005	<.001	NS	<.001


5-TG, FOOD DEPRIVED, HYPOTHERMIC
SALINE, FOOD DEPRIVED, NORMOTHERMIC
SALINE, FED, NORMOTHERMIC
PLASMA GLUCOSE (MG/DL)
400
300
200
100
PRE-RUN
POST-RUN


5-TG, FOOD DEPRIVED, HYPOTHERMIC
SALINE, FOOD DEPRIVED, NORMOTHERMIC
SALINE, FED, NORMOTHERMIC
PLASMA LACTATE (MG/DL)
100
80
60
40
20
PRE-RUN
POST-RUN


8
7
6
5
4
3
2
1
K+(MEQ/L)
5-TG, FOOD DEPRIVED, HYPOTHERMIC
SALINE, FOOD DEPRIVED, NORMOTHERMIC
SALINE, FED, NORMOTHERMIC
PRE-RUN
POST-RUN


5-TG, FOOD DEPRIVED, HYPOTHERMIC
SALINE, FOOD DEPRIVED, NORMOTHERMIC
SALINE, FED, NORMOTHERMIC
CPK (IU/L) x 10³
4
3
2
1
PRE-RUN
POST-RUN